Ultra Wideband: an Emerging Wireless Technology

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Ultra wideband (UWB) systems use precisely timed, extremely short coded pulses transmitted over a wide range of frequencies. Although UWB technology had some old roots, ultra wideband communication is a relatively new technology.

Ultra wideband communication has been the subject of extensive research in recent years due to its unique capabilities and potential applications particularly in short-range multiple access wireless communications. However, many important aspects of UWB-based communication systems have not yet been thoroughly investigated. There have been strong views expressed in the literature regarding the suitability of UWB technology to wireless communications. Research generated in industrial organizations is biased towards the advantages of UWB technology. On the other hand, the research work down playing the viability of this technology is not based on rigorous and exhaustive analyses. The objective of this paper is not to resolve this debate, but instead to obtain a more thorough and comprehensive understanding of the potentials of UWB technology by studying important attributes of UWB communication systems including historical evolution, bandwidth requirement and definition, shape and spectra of information signals, coding schemes and modulation techniques, interference, security issues, hardware aspects, and applications.

1 Background and Historical Evolution

Ultra wideband technology originated from work in time-domain electromagnetics begun in 1962. In 1978 efforts turned toward the communication using UWB signals. The term “ultra wideband” was not used until around 1989. By that time, the theory of UWB has experienced thirty years of developments.

2 Definition and Band Allocation

Before presenting a formal definition for ultra wideband signals and systems, it should be noted that different terms are used in the literature which essentially refer to the same thing such as impulse radio, orthogonal functions, nonsinusoidal, sequency theory, carrier-free, video-pulse transmission, large relative bandwidth, time-domain techniques, baseband, large-relative bandwidth and ultra wideband

There is no general definition of UWB in the IEEE dictionary. However US Defense Advanced Research Project Agency (DARPA) defined UWB for EM waves with instantaneous bandwidth greater than 25% of center frequency.

3 Communication Signal (Shape and Spectrum)

Narrowband communication is usually achieved by modulating a sinusoidal carrier with the information to be transmitted. The resultant signal possesses the sinusoidal nature and occupies a narrow band in the frequency domain. On the other hand, for UWB applications, any waveform that satisfies the definition of UWB signal can be used. The choice of a specific waveform is driven by system design and application requirements. There has been many attempts to choose a signal waveform suitable for UWB applications and yet has minimal interference with proximity systems.

The basic theoretical model for impulse radio uses a class of waveforms known as "Gaussian waveforms". They are called Gaussian waveforms because they are very similar to the Gaussian function. Gaussian excitation pulse provides excellent radiation properties. Other possible waveforms include pulse like triangular, trapezium and other shaped pulses. To get more insight on the signal shape and spectrum, one has to address the multiple access system.

4 Coding and Modulation

4.1 Coding

All source and channel coding applicable for narrowband systems are also applicable for UWB systems. The advantage for UWB communication is the fact that

UWB signals seems to be easier to deal with because the signal is readily presented in a digital form. UWB technology can be considered as the modulation layer of the communication system. Thus, the remaining coding principles for the higher-level communication layers, which are used in narrowband communications, are also valid for UWB communication

Pulse position coding or "dithering" is a basic building block of the proposed multiple access UWB system. Pseudo-random noise coding (PN Code) is used for channelization. The code is used to apply a relatively large time offset at every frame. Each user has a different code. Only the receiver with the same code can decode the transmission. In the frequency domain the PN code makes the signal like noise. The code is essential to suppress multiple access interference. PN codes must be orthogonal to one another. They must effectively smooth the energy distribution and allow fast signal locking.

4.2 Modulation

UWB signals are usually time domain modulated using pulse position modulation. This modulation allows for the use of an optimal receiving matched filter technique. Pulse position modulation is accomplished by varying the pulse position about a nominal position. For example in a 10 Mpps (Mega pulse per second) system, pulses would be transmitted nominally every 100 ns. If the information bit is "0", the pulse would be transmitted 100 ps early. For a digital bit of "1", the pulse would be transmitted 100 ps late.

5 Interference

Interference on UWB systems can result from other UWB users - multiple access-, multipath, other narrowband systems, etc. Similarly, interference to narrowband system could be multiple access, co-channel, multipath, leakage from other narrowband systems, or UWB interferences. First, the interference from other radiators to UWB systems is reviewed. Second, the interference on other narrowband systems as a result of UWB system will be discussed.

6 Hardware

The hardware requirements for UWB communications is based on sophisticated digital electronics. The basic components for UWB communications have so far been used are the following: pulse train generator, pulse train modulator, detection receivers, leading edge detector, ring demodulators, correlation detectors, signal integrators, synchronous detectors and wideband antennas.

7 Applications

The original proposal for UWB is based on the assumption that UWB is immune to multipath, can support higher rate communications, the signal has a better wall penetration capabilities, and may consume much less power. These features support many applications including indoor static wireless LANs, home-networking, asynchronous transfer mode (ATM) multimedia, un-centralized multiple access communication and secure military applications.

Besides communication applications, UWB technology has many applications in military, aviation, and space fields. UWB systems can be used for navigation and communication. It can be used for range measurements. UWB receivers can time the transmitted pulses to within a few thousand billions of seconds. By measuring the round trip delay to within that level of accuracy, it can be determined whether an aircraft's wing-flaps are up or down.

UWB technology supports integration of services. Some of the services and applications that can be integrated with UWB communications are:

Precision Geo-location Systems

Imaging

Through –Wall Sensing Radar

Underground Penetrating Radars

UWB technology is also promising in other fields such as automobile collision avoidance, computational fluid dynamics. More sophisticated applications are expected due to the recent developments in application specific integrated circuits .